MONTHLY NOTICES

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ROYAL ASTRONOMICAL SOCIETY.

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Rev. T. E. R. PHILLIPS, PRESIDENT, in the Chair.

John Alexander Armstrong, 5 King's Road, Monkseaton, Northumberland;
James Ruthven Brown, Ravenslea, Aytoun Road, Glasgow;
Andrew Fraser, M.I.E.E., 21 Esmond Road, Bedford Park, London, W. 4;
William Grant Oliver, L.D.S., Wadham House, Dorchester, Dorset;
Harold W. P. Richards, B.Sc., Belmore, King Edward Road, New Barnet, Herts, and Norman Lockyer Observatory, Sidmouth, Devon;
David Israel Slutzkin, A.R.C.S., D.I.C., 2 Exeter Road, London, N.W. 2; and
Albert Charles Stevenson, B.Sc., 19 Willow Avenue, Willowbank, Uxbridge, Middlesex,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

John Granville Hawke, Ravensfield, Northumberland Road, New Barnet, Herts (proposed by W. A. Parr);
Marie Victor Marc Herchenroder, 140 Holland Road, Kensington, London, W. 14 (proposed by H. H. Waters);

Armin Otto Leuschner, Professor of Astronomy in Berkeley University, California, U.S.A. (proposed by H. H. Turner) ; and
Llewellyn Hilleth Thomas, Trinity College, Cambridge (proposed by W. M. Smart).

The following were proposed by the Council as Associates of the Society :—

Professor Paul Guthnick, Director of Berlin University Observatory, Neu-Babelsberg, Germany ; and
Professor Michal Kamienski, Director of the University Observatory, Warsaw.

Seventy-nine presents were announced as having been received since the last meeting, including amongst others :—

A. Reymond, History of the Sciences in Greco-Roman Antiquity ; translated by Ruth Gheury de Bray (presented by M. Gheury de Bray) ;
Sydney Observatory, Astrographic Catalogue, Vols. 7 and 8 ;
Astrographic Charts : San Fernando Observatory, zone $-3°$ (10 charts) ; Bordeaux Observatory, zones $+14°$, $+12°$ (18 charts) ; Toulouse Observatory, zones $+5°$, $+7°$, $+9°$ (26 charts).

On Some New Identifications of Lines of Ionised Iron with Lines in Various Celestial Spectra. By F. E. Baxandall, A.R.C.Sc., J. A. Carroll, M.A., Ph.D., and F. J. M. Stratton, D.S.O., M.A. (Plate 7.)

(*Communicated by the Director, Solar Physics Observatory, Cambridge.*)

In a paper on " Multiplets in the Spark Spectrum of Iron " Professor H. N. Russell gives * the results of an investigation of the enhanced lines of iron, in which a list of iron spark lines—prepared by Dr. Merrill and Dr. Anderson—was used as a basis for an analysis of the structure of the spectrum. Multiplets belonging to sextet and quartet systems have been definitely traced, and 214 lines have been grouped into 35 multiplets, involving combinations between 16 terms. These lines include almost all the enhanced iron lines of astro-physical importance, such as occur in the solar spectrum, the chromosphere, the spectrum

* *Astrophysical Journal*, **64**, 194.

of α Cygni and kindred stars, and lines which are weakened in sun-spot spectra.

For the lines in his table Russell gives the wave-lengths, spark intensities, wave-numbers, and the designation by means of the terms whose combination produces each line. The lines tabulated range from λ 1550 to λ 7712, but for the points discussed in the present note only those which fall in the region λ 2944 to λ 7712 are considered. Russell's lines of lower wave-lengths are outside the range of published records relating to the light sources mentioned.

With very few exceptions, the enhanced iron lines previously identified at Kensington and elsewhere with α Cygni lines appear in Russell's list of multiplet lines. It appears certain that other iron lines which he records account for some 17 lines of α Cygni which have been tabulated as unidentified lines, while in eight other cases his extra lines are probably involved in α Cygni lines which have been ascribed to lines of other elements. Which these lines are is indicated in the series of multiplet groups tabulated later in this paper.

In reference to some of Russell's new lines he says: "A number of lines in the red which fall exactly in the position predicted by the combination principle, but have not been recorded in the laboratory, have been taken from the solar spectrum, in which they are readily distinguished by the fact that they are greatly weakened in sun-spots. . . . This behaviour is characteristic of enhanced lines and suffices to show that they belong to a spark spectrum of some sort. The excellent agreement with the computed wave-lengths indicates that they are due to iron."

In connection with the lines referred to in the previous paragraph as not having been recorded in laboratory spectra, it was suggested to us by Professor Newall that a series of plates of iron-arc spectra which he and Mr. B. Cookson obtained in 1907 should be examined to see if they reveal any of these lines. It is characteristic of the enhanced lines that they show with increased intensity near one or both poles, and in the Cambridge plates they are thus readily picked out from the general type of arc lines. They will be referred to here as "polar" lines. An examination of the plates shows that of the 27 lines indicated by Russell as not having been recorded in the iron-spark spectrum, 12 occur in the Cambridge spectra. Three of these have previously been recorded in Kensington publications as enhanced iron lines and identified with α Cygni lines. These are λλ 4385·39, 4541·52, 5362·87. The first has also been given as an enhanced line by Reese, and the third by Fowler. The remaining 9 of Russell's extra lines occurring in the Cambridge plates are indicated in the tabulated series of multiplet lines given later.

There are two enhanced lines of iron which have been previously well established, but which do not occur in any of Russell's multiplets. These are λ 4635·32 and λ 5534·84. The first was recorded in Kensington publications and is represented in the solar spectrum, the chromosphere, and α Cygni. It is well shown as a "polar" line in the Cambridge iron-arc spectra. The second was recorded by Fowler and identified with a strong chromospheric line. It is also represented in the solar spectrum

and in that of α Cygni (Miss Waterman). It is weakened in spot spectra and is a polar line in the Cambridge plates.

Discussion of the Multiplets.

In the following tables all the lines due to FeII which have been classified by Russell and which lie in the region λ 2944 to λ 7712 are set forth, together with the theoretical intensities of the iron lines and the observed intensities of the corresponding lines in various light sources. The numbers under the wave-length of each line are, in order :

Calculated Intensity [$\mathrm{Log_2}$ (Calculated Intensity)],
Rowland's Solar Spectrum Intensity,
α Cygni ,,
Chromosphere (Mitchell) ,,
Russell's Spark ,,
Cambridge Fe-Arc Plates. Polar Intensity.

The theoretical intensities are calculated by means of Kronig's formulæ, which give strictly the ratios of the numbers of transitions (each one of which yields an emission of one quantum of light) between the various levels of the two multiple terms responsible for a given multiplet. These numbers have been reduced to true intensity ratios by multiplying by the frequency of the line involved, and since integral ratios are no longer obtained, they have been reduced to give an intensity of unity for the weakest line in each multiplet. The calculated intensity-numbers in any one multiplet are merely ratios for that multiplet and cannot be compared with those in any other.

The observed intensities are " eye estimates " made in the usual way when measuring the plates. These are found in practice to be approximately proportional to the logarithms of the true (energy) intensities, and so for convenience of comparison the logarithms of the calculated intensities to the base 2 are given in brackets beside the calculated intensity.

Over a limited range of wave-length, so that the plate sensitivity is nearly constant, the observed intensities are comparable among themselves, but it is clear that very different scales have been used in the different spectra referred to in the tables. It seems best to leave the observed intensity numbers unchanged ; and in order to obtain suitable numbers for comparison the $\log_2$ (cal. int.) may be altered. In doing this it should be noted that multiplication by any factor has the effect of increasing the number of integral subdivisions in the scale between any two lines of given intensity ratio, while if any constant be added or subtracted the effect is to preserve the gradation of the scale, but to refer it to stronger or weaker images on the plate. Thus while Russell's numbers and the Cambridge numbers correspond nearly to a $\log_2$I scale, Mitchell uses a more finely-divided scale so that the log (cal. int.) needs to be multiplied by about 2·5 for comparison with them. Further, if the observed intensities are all low, it means that the lines were weakly shown on the plate, but the same multiplying factor should

be used, and to reduce the resulting calculated numbers to a low value a constant should be subtracted from all of them. In short, then, the calculated numbers may be compared with all the observed values except Mitchell's by adding or subtracting a constant chosen to give the best agreement for each multiplet, and to compare with Mitchell a factor of about 2·5 should be used first.

Unfortunately the observed values are far too rough for any elaborate comparison with theory, and, moreover, some of the multiplets are so wide that the change of plate sensitivity with wave-length is of importance, and this cannot be estimated. However, it is satisfactory to note that there is very good general agreement, and this can be taken as a confirmation of the identifications made. It is also clear that the reason why some lines have not hitherto been observed is on account of their extreme intrinsic weakness, and not because of any anomaly. Moreover, glaring discrepancies have been found to be traceable to blends with other lines, and some unsuspected ones have been thus revealed: thus, for example, the line λ 4549·48 A should be distinctly weaker than λ 4583·84 A, and this is so in the laboratory spectra, but in the chromosphere and in α Cygni it is blended with 4549·65 of Ti +, and so appears unduly strong; such lines are indicated in the tables.

In certain multiplets where no complete solution for the intensity ratios has been found, we have ventured to give the results to be obtained by an application of the sum-rule for intensities, to obtain at any rate a qualitative comparison. We should, according to Eddington, expect the intensities of stellar absorption lines to be to a first approximation proportional to the square roots of the absorption coefficients, but the observed numbers are too rough to make any comparison possible, and, moreover, the absolute scale is unknown.

The wave-lengths of a few lines that are predicted by the combination principle, but are not given in Russell's list, have been calculated by us (Table XIX.) to complete certain multiplets, and four of these have received probable identifications with observed lines. Two of them are blended with lines of Ti, and so are strengthened in the sun-spot spectrum; presumably the strengthening of the Ti + outweighs the weakening of the already very weak iron lines.

In the tables, brackets ( ) indicate a line that should exist according to the combination principle, but which has not been observed in the laboratory. Where a line falls outside the range of observation a cross (+) is placed for the corresponding intensity number, a dash (−) denotes that it has not been observed. An asterisk (*) alongside a wave-length indicates that the line has not, previously to Russell's paper, been recorded as an enhanced line. A (†) accompanying a wave-length indicates a line which, according to Russell, has not been recorded in the iron-spark spectrum, but which occurs in the Cambridge iron-arc spectrum, in nearly all cases as " polar " lines. An (*a*) preceding a wave-length signifies that the line accounts for an unidentified α Cygni line previously recorded. A (*b*) preceding a wave-length signifies that an α Cygni line previously recorded in the same position has been ascribed to a line of an element other than Fe+.

All the wave-lengths are given on the I.A. scale.

TABLE I.

$b^4F'-a^4D'$.

	$b^4F'_2$.	$b^4F'_3$.	$b^4F'_4$.	$b^4F'_5$.
$a^4D'_1$	4508·29 50 (5·6), 4, 5, 8, 8, 5.			
$a^4D'_2$	4541·52 † 20 (4·3), 2, 3, 4, —, 2.	4522·64 81 (6·3), 3, 5, 12, 6, 6.		
$a^4D'_3$	4595·70 *† 1·4 (0·5), 2, —, 2, —, 3.§	4576·31 26 (4·7), 2, 4, 4, 4, 2.	4549·48 124 (6·9), 2, 7,‖ 20,‖ 4, 6·5.	
$a^4D'_4$	..	4648·32 *† 1 (0), 000, —, 0, —, <1.	(*a*) 4620·52 *† 20 (4·3), 1, 2, 4, —, 1.	4583·84 179 (7·5), 4, 7, 15, 8, 7.

‖ These intensities respectively represent blends in α Cygni and the chromosphere of the solar lines 4549·48 Fe+ and 4549·65 Ti+.

§ This line in the Cambridge Fe plate is not shown as a "polar" line.

TABLE II.

$b^4P'-a^4D'$.

	$a^4D'_1$.	$a^4D'_2$.	$a^4D'_3$.	$a^4D'_4$.
$b^4P'_1$	4385·39 † 8 (3), 2, 6, 5, —, 2·5.	4416·81 8 (3), 2, 5, 8, 4, 2·5.		
$b^4P'_2$	(*a*) 4273·31 *† 1·6 (0·1), 3, 3, 3, 1, <1.	4303·18 10 (3·3), 2, 5, 3, 4, 3.	4351·77 20 (4·7), 5,‡ 7, 12,‖ 6, 4.	
$b^4P'_3$	..	(*a*) 4128·74 * 1 (0), 2, 3, 0, —, —.	4173·48 9 (3·1), 2, 7,§ 10,§ 6, 3.	4233·16 39 (5·3), 4, 8, 20, 8, 4.

‖ In chromosphere this intensity represents a blend of solar lines 4351·77 Fe+ Cr, and 4351·92 Mg.

‡ Solar line is a blend of Fe+ and Cr lines.

§ Probably blend here with Ti+4173·55.

TABLE III.

$b^4D - a^4P$.

	b^4D_1.	b^4D_2.	b^4D_3.	b^4D_4.
a^4P_1	(*a*) 6149·25 *	(*b*) 6147·85 *		
	8 (3), 2, –,	8 (3), 3, 2,		
	–, 4, 2.	–, 6, 3.‖		
a^4P_2	6239·95 *	6238·39	(*a*) 6247·56	
	1·6 (0·1), 00, –,	10 (3·3), 2, –,	20 (4·7), 2, 1,	
	+, –, –.	+, 4, 1.	+, 4, 2.	
a^4P_3	..	6407·30 *†	6416·92	(*b*) 6456·39
		1 (0), 0, –,	9 (3·1), 1, –,	39 (5·3), 3, 1,
		+, –, 2.‖	+, 2, 2·5.‖	+, 6, 5.

‖ These lines in the Cambridge Fe plate do not show as "polar" lines.

TABLE IV.

$a^4P' - a^4D'$.

	$a^4D'_1$.	$a^4D'_2$.	$a^4D'_3$.	$a^4D'_4$.
$a^4P'_1$	3193·81 *	3210·46		
	8·3 (3·1), 1, –,	8·3 (3·0), 1, 3,		
	+, 4, +.	+, 4, +.		
$a^4P'_2$	(*a*) 3170·35 *	3186·75 *	3213·32	
	1·7 (0·8), 2, 2½	10·6 (3·4), 3, 3½,‡	21 (44), 3, 4,	
	+, 2, +.	+, 4, +.	+, 5, +.	
$a^4P'_3$	..	(3166·45)	3192·81 *‖‡	3227·76
		1 (0·0), 1, 2,	9 (3·2), 2, –,	39 (5·3), 2, 3,
		+, –, +.	+, 3, +.	+, 7, +.

‖ Calculated λ 3192·695. See H. N. Russell (*Ap. J.*, **64**, 200).
‡ Ascribed by Wright and Applegate to Fe ? Line 3166·45 not in Russell's list. Calculated by combination principle.

TABLE V.

$a^4G - a^4F$.

	a^4G_3.	a^4G_4.	a^4G_5.	a^4G_6.
a^4F_2	5197·56 228 (7·8), 2, 3, 4, 4, 3.			
a^4F_3	(5254·94) 36·3 (5·2), 3, 1, 1, —, —.	5234·62 303 (8·2), 2, 4, 5, 4, 3.		
a^4F_4	5346·54 * 1·3 (0·4), 0, —, 1, —, —.	5325·56 47 (5·5), 2, —, 3, 4, —.	5276·01 400 (8·7), 3, 4, 10, 6, 3.	
a^4F_5	..	(5477·69) 1 (0), 00, —, 1, —, —.	5425·26 * 35 (5·1), 1, —, 4, —, —.	5316·62 520 (9·0),‖ 4, 6, 12, 8, 5.

‖ Probably blended with $a^4G_4 - a^4D_3'$ (5316·78), which is, however, exceedingly weak. The two lines with $\lambda\lambda$ in brackets not in Russell's list. Calculated by combination principle.

TABLE VI.

$a^4P' - a^4P$.

	a^4P_1.	a^4P_2.	a^4P_3.
$a^4P'_1$	2964·63 * 1·0 (0), +, +, +, 3 (blend), +.	2985·55 * 4·8 (2·2), +, +, +, 6, +.	
$a^4P'_2$	2944·40 * 4·9 (2·2), +, +, +, 6, +.	2965·04 * 1·6 (0·7), +, +, +, 4, +.	3002·65 * 5·2 (2·3), 00, +, +, 7, +.
$a^4P'_3$	..	2947·66 * 5·3 (2·3), +, +. +, 6, +.	2984·83 * 12·5 (3·5), +, +. +, 8, +.

TABLE VII.

$b^4D - a^4D'$.

	b^4D_1.	b^4D_2.	b^4D_3.	b^4D_4.
$a^4D'_1$	7224·48 *	7222·42 *		
	1 (0·0), 000 ? +,	1 (0·0), 000 ? +,		
	+, −, +.	+, −, +.		
$a^4D'_2$	7310·23 *	7308·09 *	7320·72 *	
	1 (0·0), 00 (A), +,	1·6 (0·7), −	1·4 (0·5), 1 (A),	
	+, 00 (A), +.	+, +, 000, +.	+, +, 0, +.	
$a^4D'_3$	..	7449·36 *	7462·36 *	7515·89 *
		1·4 (0·5), +, +,	3·4 (1·7), +, +,	1·1 (0·1), +, +,
		+, −, +.	+, 2, +.	+, −, +.
$a^4D'_4$	..	..	7655·47 *	7711·76 *
			1·1 (0·1), +, −,	6·5 (2·6), +, −,
			−, 00 (NA), +.	−, −, +.

TABLE VIII.

$b^4F' - a^4F$.

	$b^4F'_2$.	$b^4F'_3$.	$b^4F'_4$.	$b^4F'_5$.
a^4F_2	4491·41	(*a*) 4472·93 *		
	4·1 (2·0), 2, 4,	1·0 (0·0), 0, 2,		
	6, 2, 3.	4, −, −.		
a^4F_3	4534·17 *†	4515·34	4489·21	
	1·0 (0·0), 1, 5,‖	5·2 (2·3), 3, 5,	1·3 (0·4), 2, 3,	
	15,‖ −, 1.	6, 6, 4.	6, 4, 1.	
a^4F_4	..	(*a*) 4582·84 *†	4555·91	4520·24
		1·3 (0·4), 1, 2,	7·6 (2·8), 3, 5,	1·0 (0·0), 3, 4,
		2, −, 1.	10, 6, 4·5.	8, 6, 4.
a^4F_5	..	..	(*a*) 4666·75 *†	4629·33 ‡
			1·0 (0), 1, 3,	11·2 (3·4), 6, 6,
			3, −, <1.	12, 4, 5.

‖ This line in *α* Cygni and the chromospheric spectrum has hitherto been identified with Ti+4533·97. The line in these light sources is probably a blend of this with Russell's new Fe+ line.

‡ In sun and chromosphere probably blended with Ti and Co lines.

TABLE IX.

a^6S-a^6P.

	a^6P_2.	a^6P_3.	a^6P_4.
a^6S_3	4923·92	5018·44	5169·03
	1 (0·0), 5, 8,	1·5 (0·6), 4, 7,	2 (1·0), 4, 6,
	20, 10, 7.	15, 8, 10.	15,‡ 8, 7.‖
	5·2 (2·3).	4·0 (2·0).	9·6 (3·2).

‖ Polar intensity difficult to estimate owing to close proximity of Fe arc line 5168·88.

‡ In chromosphere, probably blend of Fe + and Fe line 5168·88.

TABLE X.

a^4D-a^6F.

	a^6F_1.	a^6F_2.
a^4D_1	2975·94 *	2979·36 *
	1 (0), ? 0, +,	2 (1·0), ? 0·0, +,
	+, 1, +.	+, 2, +.

TABLE XI.

$a^4P'-a^4F$.

	a^4F_2.	a^4F_3.	a^4F_4.
$a^4P'_1$	(*a*) 3185·33 *		
	3*x*, 2, 2,		
	+, −, +.		
$a^4P'_2$	(3161·97)	3183·13 *	
	x−18, 3, 4,	5*x*+18, 2, 3,‖	
	+, −, +.	+, 3, +.	
$a^4P'_3$	(3142·22)	(3163·10)	3196·09 *
	18, 0, −,	*x*−18, 1, −.	8*x*, 3, 4,‖
	+, −, +.	+, −, +.	+, 3, +.

Note.—P′−F "forbidden." Intensities (transition probabilities) by "sum-rule" *x* indeterminate.

‖ Ascribed by Wright and Applegate to Fe in *a* Cygni.

TABLE XII.

$b^4P'-a^4F$.

	a^4F_2.	a^4F_3.	a^4F_4.
$b^4P'_1$	(*a*) 4369·41 *		
	3*x*, 1, 2,		
	1, —, —.		
$b^4P'_2$	(*a*) 4258·16 *	4296·56	
	x−18, 1, 3,	5*x*+18, 3, 4,	
	4, —, —.	5, 6, 1.	
$b^4P'_3$	(4087·27)	(*a*) 4122·67 *	4178·87
	18, 00, —,	*x*−18, 1, 4,	8*x*, 3, 7,
	—, —, —.	3, —, —.	8, 6, 3.

See note to $a^4P'-a^4F$.

TABLE XIII.

a^4D-a^6D'.

	$a^6D'_1$.	$a^6D'_2$.	$a^6D'_3$.	$a^6D'_4$.	$a^6D'_5$.
a^4D_1	(*b*) 3303·48 *	(3314·00)			
	——, 3, 2,‖	——, 1, 1,			
	+, 1, +.	+, —, +.			
a^4D_2	(3285·42)	(*b*) 3295·83 *	(*b*) 3312·71 *		
	——, 2, 2,	——, 6, 4,‖	——, 2, 2,‖		
	+, —, +.	+, 1, +.	+, 1, +.		
a^4D_3	..	(3264·78)	3281·30	(3302·87)	
		——, 2, 2,	——, 5, 2,	——, 3, 3,	
		+, —, +.	+, 2, +.	+, —, +.	
a^4D_4	..	..	(3234·93)	3255·90	(*b*) 3277·36
			——, 0, 3,	——, 6, 3,	——, 7, 4,
			+, —, +.	+, 2, +.	+, 2, +.

‖ These lines in *α* Cygni were ascribed to lines of elements other than Fe.

TABLE XIV.

$a^6S - a^4D$.

	$a^4D'_2$.	$a^4D'_3$.	$a^4D'_1$.
a^6S_3	4601·38 *	4656·98 *†	(*a*) 4731·49 *
	1 (0·0), 00, —,	1·5 (0·6), 1, 2,‖	2 (1·0), 4, 4,
	1, —.	1,‖ —, <1.	3, 1, 3.‡

Inter-system "forbidden" combination. Intensities by sum-rule.

‖ In *α* Cygni and chromosphere hitherto identified as Ti+4657·21. The line is probably a blend of the Ti+ line and Russell's new Fe+ line.

‡ This line in the Cambridge Fe-arc plates is not shown as a "polar" line.

TABLE XV.

$a^6S - a^6F$.

	a^6F_2.	a^6F_3.	a^6F_4.
a^6S_3	(5238·64)	5256·94 *	(*a*) 5284·11 *
	1 (6·0), 000, —,	1·5 (0·6), 00, —,	2 (1·0) 1, —,
	0, —, —.	0, —, —.	3, —, —.

"Forbidden" group intensities by sum-rule. Line 5238·64 not in Russell's list. Calculated by combination principle.

TABLE XVI.

$a^4G - a^4D'$.

	$a^4D'_1$.	$a^4D'_2$.	$a^4D'_3$.	$a^4D'_4$.
a^4G_3	..	(*b*) 5264·81	(5337·74)	(5435·79)
		——, 0, —,	——, 00, 1,	——, ?, —,
		1, 1, —	2, —, —.	1, —, —.
a^4G_4	..	..	5316·78 *	(5414·06)
			——, 2,‖ —,	——, 00, —,
			—, —, —.	1, —, —.
a^4G_5	..	..	..	5362·87 †
				—, 3, 4,
				8, —, 1.
(a^4G_6)				

‖ Blend with strong Fe+ line 5316·62 ($a^4G_6 - a^4F_5$). "Forbidden" group.

TABLE XVII.

$a^6S - a^6D'$.

	$a^6D'_2$.	$a^6D'_3$.	$a^6D'_4$.
a^6S_3	6369·48 *	6432·69 *	(*a*) 6516·08 *
	1 (0·0), 0, —,	1·5 (0·6), 1, 1,	2 (1·0), 2, 2,
	+, —, —.	+, —, —.	+, 4, 1.

"Forbidden" group. Intensities by sum-rule.

TABLE XVIII.

Miscellaneous Lines.

* $b^4P'_2 - a^4P_3$?	(*a*) 3974·17 *	1, —, —, —, —.
$a^6S_3 - a^4F_4$	(*a*) 4663·71 *	0, 2, 1, —, —.
* $b^4D_3 - a^4F_3$	7301·59 *	0000 ?, +, +, 000, +.

* Part of an incompletely identified multiplet of quartet system.

TABLE XIX.

Ionised Fe *Lines.*

$\lambda\lambda$ of lines not in Russell's list, but calculated by combination principle.
(+ Signifies "out of range" of Mitchell's record).

Carroll's λ (Fe+).	Rowland's Solar Line. λ.	Int.	Or.	Chromosphere (Mitchell). λ.	Int.	Or.	α Cygni.	Int.	Or.
(3142·22)	3142·21	(0)	—		+		—		
(3161·91)	3161·94	(3)	Fe		+		3162·4	(4)	Ti+
(3163·10)	3163·08	(1)	—		+		—		
(3166·45)	3166·42	(1)	Fe		+		3166·59	(2)	—
(3234·93)	3234·92	(0)	—		+		3234·4	(3)	Cr ?
(3264·78)	3264·78	(2)	Co		+		3264·4	(2)	Cr ?
(3285·42)	3285·41	(2)	Fe		+		3285·6	(2)	—
(3302·87)	3302·85	(3)	Na ?		+		3303·2	(3)	Na ?
(3314·00)	3313·98	(1)	—		+		3314·3	(1)	Cr
(4087·27)	4087·28	(00)	—		—		—		
(5238·64)	5238·57	(000)	Ti	5238·57	(0)	Ti Sr	—		
(5254·94)	5254·95	(3)	Fe	5254·76	(1)	—	5254·6	(1)	Fe
(5337·74)	5337·75	(00)	—	5337·75	(2)	Cr	5337·8	(1)	Ti+
(5414·06)	5414·09	(00)	—	5414·05	(1)	—	—		
(5435·79)	5435·72	(0000)	—	5435·80	(1)	Ni	—		
(5477·69)	5477·69	(00)	Ti	5477·70	(1)	Ti	—		

The new lines in this list account for two hitherto unidentified lines of *α* Cygni. Four others, ascribed to Cr and Na in *α* Cygni, are probably more closely related to the Fe+ lines. Lines 3162·4 and 5337·8 are probably blends of Fe+ and Ti+ lines.

Polar Lines.—The following additional lines are shown in the Cambridge iron-arc spectra as " polar " lines, thus giving some indication of being lines of the enhanced type. None of these occurs in Russell's recent list of " multiplet " lines.

Cambridge Arc Spectrum.		Solar Spectrum (Rowland).			α Cygni.	
λ.	Int.	λ.	Int.	Or.	λ.	Int.
3843·73	1–2	3843·70	2	—	—	
3897·43	2	3897·45	2	Fe	? 3897·9	1–2
4357·15	1–2	4357·14	00	—	? 4357·6	2
4389·63	2	4389·83	0	—	—	
* 4635·32	3	4635·34	0	—	4635·5	2
4734·12	1–2	4734·12	1	Fe ?	—	
4961·90	1	4961·92	0	—	—	
5035·84	1–2	5035·90	3	Ti	—	
5100·82	2	—	—	—	—	
* 5534·84	<1	5534·82	2	Fe	5534·3	1

* These are well-established enhanced lines of iron, which have been identified previously with stellar, chromospheric, and solar lines.

References.

The following references were used in the compilation of the present paper :—

Fe+ *Lines*—
H. N. Russell, *Ap. J.*, **64**, 194.
A. Fowler, *M.N.R.A.S.*, **67**, 154.

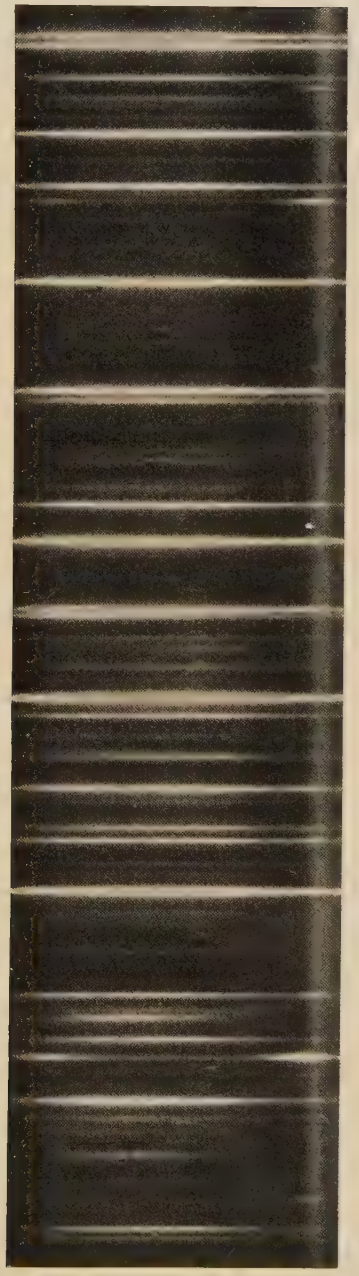
Solar Lines—
Rowland's *Tables of Solar-spectrum Wave-lengths.*

Chromosphere—
S. A. Mitchell, *Ap. J.*, **38**, 407.

α Cygni—
Publications of the Solar Physics Committee: *Catalogue of* 470 *of the Brighter Stars*, p. 30; *Spectra of the Brighter Stars in the Green Region*, p. 29.
W. H. Wright, *Lick Obs. Bull.*, **10**, 108.
Miss Waterman, *ibid.*, **8**, 1.
W. H. Wright and D. Applegate, *ibid.*, **12**, 18.

Description of the Plate.

The reproduction shows the Cambridge arc spectrum of iron in the region λ 4573 to λ 4640. The enhanced or ionised iron lines are shown as lines considerably strengthened near the poles. These are referred to in the paper as " polar " lines. The lines marked * are two of a number of new lines which Russell has, from theoretical considerations, found to belong to ionised iron. These two, with several others, are indicated by Russell as lines which have never been recorded in the iron-spark spectrum. Each of the two accounts for an α Cygni line previously unidentified.



Cambridge Spectrum of Fe Arc showing Enhanced Lines intensified near Poles.

Some Computational Problems arising in Eclipses. By L. J. Comrie, M.A., Ph.D.

Summary.—Formulæ are given for obtaining the position angles of the cusps from the Besselian elements. A simple method of obtaining the position and shape of the Moon's shadow on the Earth is given. The preparation of the Ordnance Survey Eclipse Map is described. The geometry of the method of taking long-focus photographs of the eclipsed Sun on a moving plate is developed rigorously. The formula for reducing the diameter of the Moon as measured on a photograph to its geocentric value is investigated. Finally, the corrections to the Besselian elements for the eclipse of 1927 June 29, to bring them into accord with recent observations of the Sun and Moon, are given, together with a recomputation of the central line from the revised elements.

Introduction.—It has fallen to the writer, on more than one occasion, to compute certain results appertaining to the observation of eclipses, after deriving the necessary formulæ. As these formulæ are not to be found in text-books it seems appropriate to put them on record now, at a time when the attention of English astronomers is being directed to the forthcoming total eclipse of June 29. Moreover, it is believed that the formulæ relating to the cusps will prove to be of immediate value to astronomical physicists attempting to photograph the flash spectrum.

Historical.—A century ago the circumstances of eclipses were computed by the so-called method of semi-diameters, which involved heavy interpolation from the ephemeris and the rigorous computation of parallaxes and augmentations. Bessel,* in his masterly *Analyse der Finsternisse*, was the first to simplify the problem, and the principles of his method, so ably expounded and reduced to working form by Chauvenet † more than seventy years ago, remain to this day fundamental in this branch of astronomy. A later work by Buchanan ‡ contributes nothing new to the theory, but purports to be a practical exposition of the predicting practice adopted in the office of the *American Ephemeris and Nautical Almanac.* Its helpfulness is somewhat marred by the extraordinary number of misprints that it contains.

Besselian Elements.—The *Nautical Almanac* gives the "Besselian Elements" of each solar eclipse, and from these the prediction of the circumstances—times, position angles, and magnitude—for a given place is a matter of simple straightforward calculation. For the definitions and geometrical significance of the elements the reader must consult the works already cited (all of which, unfortunately, are out of print), or the *American Ephemeris.* It should be remarked that in the computation of the Besselian elements the so-called "eclipse" semi-diameters of the Sun and Moon are employed, and that a correction is

* *Astronomische Untersuchungen*, II, 95.

† William Chauvenet, *A Manual of Spherical and Practical Astronomy.* (Philadelphia, J. B. Lippincott Company.)

‡ Roberdeau Buchanan, *The Mathematical Theory of Eclipses according to Chauvenet's Transformation of Bessel's Method.* (Philadelphia, J. B. Lippincott Company, 1904.)

applied to the tabular position of the Moon, although, curiously, not to that of the Sun. For the eclipse of June next the correction applied was $+ 7''{\cdot}0$ in mean longitude and $- 0''{\cdot}5$ in latitude, which becomes $+ 7''{\cdot}2$ and $+ 0''{\cdot}1$ in actual longitude and latitude respectively, or $+ 0^s{\cdot}53$ and $- 0''{\cdot}2$ in Right Ascension and Declination. This correction, although applied nearly three years ago, is very close to that determined by more recent observations of the Moon.

Position Angles of Cusps.—In determining the position angles of the cusps at a given moment the Besselian computation proceeds to the point where L, m, and M are known. L is the radius of the penumbra on a plane through the observer and parallel to the fundamental plane. M is the position angle of the centre of the Moon referred to the centre of the Sun, or the direction of greatest obscuration, the direction of greatest illumination being $M \pm 180°$.

The apparent semi-diameter of the Moon (including the effect of augmentation) is

$$\frac{0{\cdot}5459}{2L - 0{\cdot}5459} \times \text{Sun's semi-diameter},$$

or, for the coming eclipse as seen from England,

$$1{\cdot}007 \times \text{Sun's semi-diameter}.$$

The distance of the Moon's centre from that of the Sun is

$$\frac{2m}{2L - 0{\cdot}5459} \times \text{Sun's semi-diameter}.$$

The maximum angular breadth of the obscured portion of the Sun is

$$\frac{2(L - m)}{2L - 0{\cdot}5459} \times \text{Sun's semi-diameter}.$$

The maximum angular breadth of the illuminated portion is

$$\frac{2(L + m - 0{\cdot}5459)}{2L - 0{\cdot}5459} \times \text{Sun's semi-diameter}.$$

The magnitude of the eclipse, or the fraction of the Sun obscured at the given moment, is

$$\frac{L - m}{2L - 0{\cdot}5459}.$$

If we define an auxiliary angle A by

$$\tan^2 \frac{A}{2} = \frac{(L - m)(0{\cdot}5459 - L + m)}{(L + m)(L + m - 0{\cdot}5459)}$$

then the position angles of the cusps, reckoned from the north point through the east in the usual way, will be $M \pm A$. The "overhang" of the Moon 1° from the cusp is approximately

$$\frac{2 \sin 1^\circ \, m \sin A}{0{\cdot}5459} \times \text{Sun's semi-diameter},$$

or, for this eclipse, $60'' \, m \sin A$.

The angular distance, in degrees, from either cusp to the point where the Moon forms an imaginary cusp with a stratum of the Sun's atmosphere S seconds of arc above the adopted radius is

$$\frac{0{\cdot}5459\ S}{2 \sin 1^\circ\ m \sin A \times \text{Sun's S. D.}}$$

or, for this eclipse,

$$\frac{S}{60\ m \sin A}.$$

This formula, which is a differential one, must not be used if the resulting angular distance is more than 3° or 4°.

Those who wish to prepare diagrams illustrating the appearance of the uneclipsed portion of the Sun at any moment will, of course, regard the Sun's semi-diameter as unity in the formulæ above. The position angles from the vertex are obtained by diminishing those from the north point by C, the parallactic angle, computed, together with the altitude of the Sun, from

$$\begin{aligned} \sin \text{altitude} &= \sin\phi \sin d + \cos\phi \cos d \cos(\mu - \lambda) \\ \sin C &= \cos\phi \sin(\mu - \lambda) \sec \text{altitude} \end{aligned}$$

in which $\cos C$ has the same sign as η. In most cases, however, since a possible error of 0°·2 in C will be considered negligible, we may use

$$\tan C = \frac{\xi}{\eta}$$

while the altitude may be found from

$$\sin \text{altitude} = \zeta$$

For an observer in or near the track of totality it will be found that M and the position angles of the cusps vary very rapidly just before and just after mid-eclipse, so that their computation cannot be checked by differences, even if computed at 5-minute intervals. On the central line these angles will, of course, change 180° or so in the minute containing the mid-eclipse, while even in London the change is as large as 20° in this minute. It will, however, suffice to compute the quantities $x - \xi$, $y - \eta$, and L at intervals of 10^m (or 5^m if great accuracy is desired) and then to interpolate them to the desired interval—say 1^m if a flash spectrum programme is to be attempted. Each individual m, M, and A can then be computed.

Shape of the Moon's Shadow.—Another problem that has arisen is the determination of the position and shape of the Moon's shadow on the Earth at a given moment. The rigorous formulæ for the outline are given by Chauvenet, but a simpler and only slightly less accurate solution will usually suffice. The shadow may be regarded as an ellipse, centred at that point on the central line at which mid-eclipse occurs at the given moment, and whose major axis is directed towards the Sun, the azimuth of which may be found by the usual formula. The length of the semi-minor axis b in miles is

$$3963(l_2 - \zeta \tan f_2),$$

the semi-major axis being

$$b \text{ cosec (Sun's altitude)}.$$

It may perhaps be noted that the line of equal times of mid-eclipse shown on the eclipse maps (e.g. *B.A.A. Handbook*) does not correspond to the major axis of the ellipse, but to the diameter joining the points of tangency with the northern and southern limits of totality.

Ordnance Survey Eclipse Map.—When the writer was called upon recently to compute the data for the Ordnance Survey Eclipse Map he was faced with the problem of finding the loci of points at which the time, altitude, and magnitude at mid-eclipse had definite pre-determined integral values. This is exactly the reverse of the usual application of the Besselian elements, and is not dealt with in the text-books. A brief investigation indicated that the development of the formulæ necessary for a direct solution would be exceedingly difficult and tedious, and that the formulæ when derived would be most unwieldy. The following simpler plan was therefore adopted. The values of the three quantities involved were computed rigorously by the usual formulæ for the points of intersection of each integral degree of latitude between 52° and 56° inclusive with each integral degree of longitude between 0° and + 5°. Actually the full computation was made for about half of the points involved, the values for the other points being obtained by interpolation. The quantities thus obtained were differenced along each degree of latitude and along each degree of longitude. This served the double purpose of checking, and of preparation for the next and final step, which consisted of determining by inverse interpolation the longitude along each parallel of latitude, and the latitude along each meridian of longitude at which the quantity under consideration attained its predetermined values. Thus, for $\lambda = 2°$ the times of mid-eclipse and their first differences were found to be

ϕ	G.M.T.	
°	h m	m
52	5 21·23	
		+1·49
53	5 22·72	
		+1·52
54	5 24·24	
		+1·54
55	5 25·78	
		+1·55
56	5 27·33	

G.M.T.	ϕ	
h m	° ′	′
5 21	51 51	
		+40
5 22	52 31	
		+40
5 23	53 11	
		+40
5 24	53 51	
		+39
5 25	54 30	
		+39
5 26	55 9	
		+38
5 27	55 47	

from which we obtain immediately the table on the right.

In addition to the numerical check afforded by the differencing of the values for $\lambda = 2°$ *inter se*, they are also checked by differencing with $\lambda = 1°$ and $\lambda = 3°$. Thus, although the method lays no claim to mathematical elegance, it is most satisfactory from the computer's

viewpoint because of the checks afforded throughout by the two-directional differencing, and likewise from the draughtsman's because one co-ordinate of each point to be plotted is an integral degree of latitude or of longitude.

The central line of total eclipse was found by determining the point of maximum magnitude in any direction, and its agreement with the line given in the *Nautical Almanac* serves as a concluding check. Its co-ordinates, as given to the draughtsman, may be put on record here.

λ	ϕ	ϕ	λ
°	° ′	°	° ′
1	54 49	53	+4 5
2	54 14	54	+2 23
3	53 38	55	+0 42
4	53 3		
5	52 29		

An alternative and better way of obtaining the central line would have been to compute for each point the value of Δ, the minimum distance of the Moon's centre from that of the Sun, from

$$\Delta = m \sin (M - N)$$

and then interpolate to determine points where $\Delta = 0$.

The fact that the curves showing altitude at mid-eclipse are not at right angles to the direction of the Sun has evoked comment. The explanation lies in the fact that the curves show, not simultaneous altitudes of the Sun, but altitudes at a varying time, namely, the time of mid-eclipse.

Photography of Eclipsed Sun with a Moving Plate.—The following problem arose in connection with the eclipse expedition of the Sproul Observatory of Swarthmore College, Pennsylvania, to Mexico in 1923 September, but is of general interest. The exact site was not known when the expedition left Swarthmore, but to avoid the necessity for anything but the simplest calculations in the field all quantities relating to the adjustment of the instruments were to be expressed in terms of their values for an assumed longitude, latitude, and altitude above sea-level, together with the variations for one minute of longitude and of latitude respectively.

Consider first the time of mid-eclipse. The Besselian equations with which we shall be concerned are

$$\begin{aligned} \xi &= \rho \cos \phi' \sin (\mu - \lambda) \\ \eta &= \rho \sin \phi' \cos d - \rho \cos \phi' \sin d \cos (\mu - \lambda) \end{aligned} \quad . \quad (1)$$

$$\begin{aligned} m \sin M &= x - \xi \\ m \cos M &= y - \eta \end{aligned} \quad . \quad . \quad . \quad . \quad (2)$$

$$\tau = - \frac{m \cos (M - N)}{n} \quad . \quad . \quad . \quad (3)$$

τ is the correction to be added to the time assumed for the computation in order to give the time of mid-eclipse. At the moment of mid-eclipse $M - N = \pm 90°$, so that if the time has been correctly assumed $\cos(M - N) = 0$, and hence $\tau = 0$. We shall determine first the changes in ξ, η, and m on the assumption that the latitude and longitude only are changed, and then the resulting change in τ, which will be the correction to be applied to the G.M.T. of mid-eclipse at the original station to give the time at the new station.

Differentiating (1)

$$d\xi = -\rho \cos\phi' \cos(\mu - \lambda)\, d\lambda - C^2 \rho \sin\phi' \sin(\mu - \lambda)\, d\phi \qquad (4)$$

$$d\eta = -\rho \cos\phi' \sin d \sin(\mu - \lambda)\, d\lambda + (C^2 \rho \sin\phi' \sin d \cos(\mu - \lambda) + SC\rho \cos\phi' \cos d)\, d\phi \qquad (5)$$

where

$$S = \frac{\rho \sin\phi'}{\sin\phi} \quad \text{and} \quad C = \frac{\rho \cos\phi'}{\cos\phi}$$

their values being tabulated in the *Nautical Almanac* for 1929 on pages 567–8. Differentiating (2)

$$\sin M\, dm + \cos M\, m\, dM = -d\xi$$
$$\cos M\, dm - \sin M\, m\, dM = -d\eta$$

from which

$$m\, dM = -\cos M\, d\xi + \sin M\, d\eta \qquad (6)$$

Differentiating (3) and neglecting the very small changes in n and N

$$n\, d\tau = -\cos(M - N)\, dm + \sin(M - N)\, m\, dM \qquad (7)$$

In this equation and in (6) we may now put $M - N = \pm 90°$. If also we write

$$p \sin P = \sin N$$
$$p \cos P = \cos N \sin d$$

so that

$$\tan P = \frac{\tan N}{\sin d} = \frac{x' - \xi'}{(y' - \eta') \sin d} \qquad (8)$$

P being in either of the quadrants in which the sign of $\tan P$ is satisfied, and replace the differentials $d\lambda$ and $d\phi$ by finite differences $\Delta\lambda$ and $\Delta\phi$ in minutes of arc, the expression for ΔT in seconds of time becomes

$$\Delta T = a\, \Delta\lambda + b\, \Delta\phi . \qquad (9)$$

where

$$a = -\frac{60 \sin 1'}{n} \rho \cos\phi' \sin(\mu - \lambda + P) \sin N \operatorname{cosec} P$$

$$b = \frac{60 \sin 1'}{n} (\rho \sin\phi' \cos(\mu - \lambda + P) \sin N \operatorname{cosec} P + SC\rho \cos\phi' \cos d \cos N) \qquad (10)$$

This expression was tested numerically for the June eclipse for a point at $\lambda = +3°$, $\phi = +54°$, and was found to yield times not more

than 1^s in error within a radius of 50 miles of the origin mentioned. The error varies approximately as the square of the distance.

The equations for determining the semi-duration S are

$$\Delta = m \sin (M - N) \quad . \quad . \quad . \quad (11)$$

$$\sin \psi = \frac{\Delta}{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

$$S = \frac{L \cos \psi}{n} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

L being here the radius of the umbra. At mid-eclipse $\frac{d\Delta}{dT} = 0$; in fact, this is the condition for mid-eclipse. Let Δ_0 be the value of Δ at the primary station and let it have strictly the sign given by (11), m being regarded as positive. We find quite readily

$$\Delta = \Delta_0 + f \Delta\lambda + g \Delta\phi \quad . \quad . \quad . \quad (14)$$

where

$$\tan Q = \tan N \sin d \quad . \quad . \quad . \quad (15)$$

$$\begin{aligned} f &= \rho \cos \phi' \cos (\mu - \lambda + Q) \cos N \sec Q \sin 1' \\ g &= C^2 \rho \sin \phi' \sin (\mu - \lambda + Q) \cos N \sec Q \sin 1' \\ &\quad + SC \rho \cos \phi' \cos d \sin N \sin 1' \end{aligned} \quad (16)$$

Neglecting the small changes in L and n, equations (12) and (13) yield the semi-duration at the new station. It will be noted that (12) gives two solutions for ψ differing by 180°, yielding two equal and opposite values of S in (13).

If the distance between the two stations is large, and especially if the eclipse is long, the final computation of the times of beginning and ending must not be replaced by this differential process, which, however, affords an ample check, and may be very helpful when topographical or other conditions necessitate the investigation of sites somewhat removed from the central line.

The principal instrument of the Sproul Expedition was a lens of 65 feet focal length mounted at the top of a tower nearly 50 feet high, the optical axis being directed towards the part of the heavens which the Sun would occupy at mid-eclipse. The motion of the Sun was counteracted, not by moving the lens, but by giving the photographic plate a motion equal to that of the image of the Sun. This method was first used by Schaeberle * in the Lick Expedition to Chile in 1893, but some improvements in design were introduced by Professor J. A. Miller in 1923. It eliminates the necessity for a siderostat, the figure of whose mirror is liable to change during the varying temperatures of an eclipse.

Suppose the telescope directed towards the Sun at the middle of the eclipse. Imagine a plane, to be called the normal plane, at right angles to the optical axis of the telescope. The inclination of this plane to the horizontal plane will therefore be the same as the Sun's zenith

* *Contributions from Lick Observatory*, No. 4, pp. 2 and 35.

distance, while its normal has the same azimuth as the Sun. The moving image of the Sun's centre, in travelling across this plane, will make an angle Q with the horizon, or with the intersection of the normal and horizontal planes.

Take now another plane, to be called the track carrier, such that its intersection with the normal plane is inclined to the horizontal at an angle Q, while the normal to the intersection is parallel to the horizon. An alternative conception of the track-carrier plane is that it is the plane of a rectangular plate placed so that one edge is in contact with the normal plane and is parallel to the line of motion of the Sun, the edge at right angles being in the horizontal plane.

In the track-carrier plane are placed two rails perpendicular to the intersection with the horizon, and which carry a moving carriage. This carriage in turn supports a plane parallel to the normal plane, and on which the photographic plates are to be laid. If now the carriage is moved at the appropriate rate by means of clockwork, the image of the Sun will remain stationary on the photographic plate, which now lies in the focal plane of the lens.

We require therefore the following quantities :—

Z, the zenith distance of the Sun's centre, corrected for refraction and parallax,
A, the azimuth of the Sun, reckoned from the north towards the east,
B, the azimuth of the track carrier, in the direction in which it rises,
T, the inclination to the horizon of the track carrier,
P, the angle between the track carrier and the photographic plate,
R, the rate of the moving carriage.

For the time of mid-eclipse we must know

h, the Sun's hour angle,
δ, the Sun's geocentric declination,
q, the Sun's parallactic angle,
k, the coefficient of refraction in seconds, corrected, if necessary, for altitude above sea-level.

The formulæ for obtaining A, q, and z, the uncorrected zenith distance, are given for the sake of completeness. Let

$$\tan M = \tan\delta \sec h \qquad \tan N = \tan\phi \sec h$$

M and N being in either of the quadrants in which the signs of their tangents are satisfied. Then

$$\begin{aligned} \tan A &= -\tan h \cos M \operatorname{cosec}(M-\phi) \\ \tan q &= \tan h \cos N \operatorname{cosec}(N-\delta) \\ \tan z &= \tan(M-\phi)\sec A \\ &= \tan(N-\delta)\sec q \end{aligned}$$

The quadrants of A and q are determined by the fact that $\tan z$ must be positive. The agreement of the two values for $\tan z$ serves as a partial check. Z follows at once from

$$Z = z - k\tan z + 8''\cdot 8 \sin z \quad . \quad . \quad . \quad (17)$$

The angle Q, or the angle which the direction of the Sun's motion makes with the horizon, is given by

$$\tan Q = \frac{dZ}{dA \sin Z} \quad . \quad . \quad . \quad . \quad (18)$$

If it were not for the existence of parallax, refraction, and the movement of the Sun in declination we should have

$$\tan Q = \frac{dz}{dA \sin z}$$

which may be shown to be $= \tan q$, so that Q would be $= q$, a result that is easily deduced from first principles. We shall therefore determine the corrections to be added to q to give Q.

Substituting (17) in (18) we have

$$\tan Q = \frac{dz}{dA \sin z} \frac{(1 - k \sec^2 z \sin 1'' + 8{\cdot}8 \cos z \sin 1'')}{(1 - k \sin 1'' + 8{\cdot}8 \cos z \sin 1'')}$$

$$= \tan q \, (1 - k \tan^2 z \sin 1'')$$

so that the correction to q becomes

$$- k \sin q \cos q \tan^2 z$$

which is independent of the parallax.

To determine the effect of the changing declination of the Sun we may write

$$\frac{dz}{dh} = \cos \delta \sin q - \cos q \frac{d\delta}{dh}$$

$$\frac{dA}{dh} = \frac{\cos \delta \cos q}{\sin z} + \frac{\sin q}{\sin z} \frac{d\delta}{dh}$$

from which

$$\frac{dz}{dA \sin z} = \tan q - \sec^2 q \sec \delta \frac{d\delta}{dh}$$

and if $\Delta\delta$ is the variation per hour of the Sun's Declination in seconds of arc the correction to q becomes

$$- 3{\cdot}93 \sec \delta \, \Delta\delta$$

which is independent of the observer's location. We thus have, finally,

$$Q = q - k \sin q \cos q \tan^2 z - 3{\cdot}93 \sec \delta \, \Delta\delta \quad . \quad (19)$$

The first correcting term amounts to about $+ 10'$ in the coming eclipse as seen from England, while the second term may amount, when the Sun is near the equator, to $\pm 4'$.

To find the relations between A, Q, Z, P, T, and B, take a sphere of unit radius centred at the common point of intersection of the horizontal, normal, and track-carrier planes. If we take three points, A, B, and C, such that

A is in the intersection of the normal and horizontal planes,

B is in the intersection of the normal and track-carrier planes,

C is in the intersection of the horizontal and track-carrier planes,

we shall then have a spherical triangle in which

$$\begin{aligned} A &= 180^\circ - Z & a &= 90^\circ \\ B &= P & b &= B - A \\ C &= T & c &= Q \end{aligned}$$

from which we obtain immediately

$$\begin{aligned} \tan P &= \cos Q \tan Z \\ \sin T &= \sin Q \sin Z \\ \cot (B - A) &= \tan Q \cos Z \end{aligned} \quad . \quad . \quad . \quad (20)$$

Some conventions regarding signs and quadrants will be necessary. It will be found convenient to disregard the sign of $\sin Q$ and $\cos Q$, taking P and T in the first quadrant always. Tan Q, however, must receive its correct sign, which leads to two values of B differing by 180°. It may safely be left to common sense to determine which is the elevated end of the track, while it is obvious that the moving carriage must ascend when the Sun is west of the meridian and *vice versa*.

In order to determine the rate of the carriage we must know the distance C travelled by the Sun in unit time. It is evident that

$$dC = \frac{dZ}{\sin Q}$$

Hence

$$\frac{dC}{dh} = \frac{dz}{dh} \frac{(1 - k \sec^2 z \sin 1'' + 8{\cdot}8 \cos z \sin 1'')}{\sin q \,(1 + \cot q \, dq)}$$

and since

$$\frac{dz}{dh} = \cos \delta \sin q - \cos q \frac{d\delta}{dh}$$

we have, utilising the value of dq found in the development of (19)

$$\begin{aligned} \frac{dC}{dh} &= \left(\cos \delta - \cot q \frac{d\delta}{dh}\right)(1 - k \sec^2 z \sin 1'' + 8{\cdot}8 \cos z \sin 1'') \\ &\qquad \times \left(1 + k \cos^2 q \tan^2 z \sin 1'' + \cot q \sec \delta \frac{d\delta}{dh}\right) \\ &= \cos \delta \{1 - k (\sec^2 z - \cos^2 q \tan^2 z) \sin 1''\} \end{aligned}$$

neglecting second order terms and the effect of parallax, which is seen to be less than 1 part in 20,000. It will be observed that the Sun's changing declination produces no effect, a result that is easily confirmed geometrically. The effect of differential refraction, which always decreases the apparent rate of movement of the Sun, varies from a minimum of 1 part in 3500 (regardless of the latitude or altitude) when the Sun is on the meridian, to a maximum of 1 part in 3500 $\cos^2 z$ when the Sun is at elongation, which can only occur in the tropics. For the coming eclipse as seen from England the effect is about 1 part in 200.

In one hour of mean time h will increase by $3609^s{\cdot}86 - \Delta\alpha$, where $\Delta\alpha$ is the variation per hour of the Sun's R.A. in seconds of time, as

given in the *A.E.** Denoting by f the focal length of the lens and by g the quantity

$$\frac{3609{\cdot}86 - \Delta a}{3600} \times 900 \sin 1''$$

Δa	g
8·892	
	0·004364
9·717	
	0·004363
10·542	
	0·004362
11·367	

as tabulated in the accompanying critical table, we have for R, the rate of the carriage per minute in the same units as f

$$R = fg \cos\delta\{1 - k(\sec^2 z - \cos^2 q \tan^2 z) \sin 1''\} \quad . \quad (21)$$

R is independent of any small change in the longitude and latitude.

It is necessary to know the error E of the moving plate at the end of an exposure of t minutes, due to the use of the uniform rate R and a straight track. This will be

$$\frac{t^2}{2}\sqrt{\left(\frac{d^2z}{dh^2}\right)^2 + \left\{\frac{d}{dh}\left(\frac{dA \sin z}{dh}\right)\right\}^2}.$$

We find easily

$$\frac{d^2z}{dh^2} = -\frac{\cos\phi \cos\delta \cos A \cos q}{\sin z}$$

$$\frac{d}{dh}\left(\frac{dA \sin z}{dh}\right) = \frac{\cos\phi \cos\delta \cos A \sin q}{\sin z}$$

so that

$$E = \frac{1''{\cdot}96 \cos\phi \cos\delta \cos A}{\sin z} t^2 \quad . \quad . \quad . \quad (22)$$

To express the changes in Z, A, Q, etc. in terms of the differences between the adopted and assumed longitude and latitude of the observing station we first write the differentials of the PZS triangle.

$$dz = \cos\delta \sin q\, dh - \cos A\, d\phi - \cos q\, d\delta$$

$$dA = \frac{\cos\delta \cos q}{\sin z} dh + \cot z \sin A\, d\phi + \frac{\sin q}{\sin z} d\delta$$

$$dq = -\frac{\cos\phi \cos A}{\sin z} dh + \frac{\sin A}{\sin z} d\phi + \cot z \sin q\, d\delta.$$

Since these formulæ are not intended to be used for distances greater than 20 or 30 miles from the assumed station the influence on the correcting terms in Z and Q will not exceed $0'{\cdot}1$, so we may write

$$dh = \frac{a}{4}\Delta\lambda + \frac{b}{4}\Delta\phi - \Delta\lambda$$
$$d\phi = \Delta\phi \qquad d\delta = 0$$
$$dz = \Delta Z \qquad dq = \Delta Q$$

* Variations per hour will be given in the *N.A.* for 1931 and subsequent years.

a and b being defined in equation (10). Hence

$$\Delta Z = \cos\delta \sin q \left(\frac{a}{4} - 1\right)\Delta\lambda + \left(\frac{b}{4}\cos\delta \sin q - \cos A\right)\Delta\phi$$

$$\Delta A = \frac{\cos\delta \cos q}{\sin z}\left(\frac{a}{4} - 1\right)\Delta\lambda + \left(\frac{b}{4}\frac{\cos\delta \cos q}{\sin z} + \cot z \sin A\right)\Delta\phi$$

$$\Delta Q = -\frac{\cos\phi \cos A}{\sin z}\left(\frac{a}{4} - 1\right)\Delta\lambda + \left(\frac{\sin A}{\sin z} - \frac{b}{4}\frac{\cos\phi \cos A}{\sin z}\right)\Delta\phi \quad (23)$$

The equations (20) for P, T, and B are so simple that it seems unnecessary to carry the differential process any further. The coefficients of $\Delta\lambda$ and $\Delta\phi$ are readily computed beforehand, so that the observer, having ascertained the longitude and latitude of his station, is able to obtain all the numerical data for the erection of his instruments with not more than ten minutes computation, and without reference to the *Nautical Almanac*.

This analysis has dealt only with the geometrical and spherical aspect of the problem. Mechanical and optical aspects have been purposely omitted. It is evident that the lens must be one giving good definition over a rather large field, especially in a long eclipse. The longest exposures will probably be given at mid-eclipse.

Determination of the Moon's Semi-diameter by Photography.—During the eclipse of 1923 September 10 Professor Miller * secured, at the request of Professor C. L. Poor, instantaneous photographs of the Moon projected against a background of corona. The scale of the plate was determined by a longer exposure in which star images were recorded. The problem to be discussed is that of reducing the measured diameters to their geocentric values.

Let

S = geocentric semi-diameter.
S' = augmented semi-diameter uncorrected for refraction.
S'' = the augmented semi-diameter making an angle θ with the vertical circle through the centre of the Moon, corrected for refraction.
a, b = the augmented horizontal and vertical semi-diameters, corrected for refraction.
π = Moon's equatorial horizontal parallax.
δ, h = Moon's geocentric declination and hour angle.
$K = k \sin 1'' =$ constant of refraction.

We derive from first principles (Chauvenet, p. 184)

$$\sin S' = \sin S \frac{\sin(\gamma - \delta')}{\sin(\gamma - \delta)} \quad . \quad . \quad . \quad (24)$$

in which

$$\alpha - \alpha' = \pi\rho \cos\phi' \sin h \sec\delta$$

$$\tan\gamma = \tan\phi' \cos\left(\frac{\alpha - \alpha'}{2}\right) \sec\left(h + \frac{\alpha - \alpha'}{2}\right)$$

$$\delta - \delta' = \pi\rho \sin\phi' \sin(\gamma - \delta) \operatorname{cosec}\gamma \quad . \quad . \quad (25)$$

* *Ap. J.*, **61**, No. 3 (March 1925), or *Sproul Observatory Publications*, No. 7.

From these we find

$$\gamma = \gamma_0 + \Delta\gamma \quad . \quad . \quad . \quad . \quad (26)$$

where

$$\tan\gamma_0 = \frac{\tan\phi'}{\cos h} = \frac{[9{\cdot}9971]\tan\phi}{\cos h} \quad . \quad . \quad . \quad (27)$$

$$\Delta\gamma = \frac{\pi}{2}\rho\sin\phi'\tan^2 h\sec\delta\cos^2\gamma_0 \quad . \quad . \quad (28)$$

From (24) and (25), neglecting third order terms,

$$S' = S\left(1 + m - \frac{m^2}{2}\tan^2(\gamma - \delta)\right) \quad . \quad . \quad (29)$$

where

$$m = \frac{\sin\pi\rho\sin\phi'\cos(\gamma - \delta)}{\sin\gamma} \quad . \quad . \quad . \quad (30)$$

Turning now to the effect of refraction, unless the altitude is very small we may regard the Moon as an ellipse having semi-axes a and b where

$$a = S'(1 - K) \qquad b = S'(1 - K\sec^2 z) \quad . \quad (31)$$

The diameter S'' as defined above will be

$$S'' = \frac{ab}{\sqrt{a^2\cos^2\theta + b^2\sin^2\theta}}.$$

Putting

$$\tan\theta' = \frac{b}{a}\tan\theta$$

$$= \tan\theta(1 - K\tan^2 z)$$

we find

$$S'' = \frac{b\cos\theta'}{\cos\theta}$$

$$= S'(1 - K - K\tan^2 z\cos^2\theta) \quad . \quad (32)$$

$$= S'(1 - K\sec^2\psi) \quad . \quad . \quad . \quad (33)$$

if we put

$$\tan\psi = \tan z\cos\theta \quad . \quad . \quad . \quad . \quad (34)$$

In the present case individual diameters as given by (33) are not required, for we see from (32) that the mean of two semi-diameters at right angles, or any even number in pairs at right angles, is

$$\bar{S} = S'\left(1 - K - \frac{K\tan^2 z}{2}\right) \quad . \quad . \quad . \quad (35)$$

Introducing (29) in (35) and inverting

$$S = \bar{S}\left\{1 + K + \frac{K\tan^2 z}{2} - m + \frac{m^2}{2}\left(1 + \sec^2(\gamma - \delta)\right)\right\} \quad (36)$$

which is the reduction formula required.

It may be urged that this treatment of the refraction assumes the lower half of the Moon to have exactly the same shape as the upper half. This is justified, because the distance from the refracted centre of the Moon to the refracted vertex cannot exceed the distance from centre to anti-vertex by as much as 0″·1 if the altitude is greater than 17°. Further, in actual measuring, full diameters and not semi-diameters are necessarily measured. The formula is far more exact than any measures can ever be.

Correction of the Besselian Elements in the "Nautical Almanac."—The Astronomer Royal has kindly quoted the corrections to the mean longitude of the Sun and Moon, as determined by recent observations at the Royal Observatory, as + 1″·6 and + 6″·5 respectively. The only Besselian elements affected by substituting these corrections for those actually used in the *Nautical Almanac* are x and y, which should receive constant corrections of − 0·00060 and + 0·00003 respectively. Times computed from the corrected elements will be nearly four seconds later than those derived from the published elements.

A recomputation of the central line with the revised elements shows that it will be displaced one mile and a third to the north, or just one mile to the north-west, in a direction parallel to itself. The co-ordinates of the central line, and the circumstances of the eclipse along this line, are given in the table below.

G.M.T.	Longitude.	Latitude.	Sun's Altitude.	Sun's Azimuth.	Shadow-Ellipse. Axes in Miles. Major.	Minor.	Eccentricity.	Duration.
h m s	° ′	° ′	°	°				s
5 23 0	+4 55·0	52 32·1	9·8	64·2	81	13·7	0·985	20·9
10	4 35·6	52 43·3	10·1	64·5	80	13·9	·985	21·2
20	4 16·7	52 54·3	10·3	64·8	78	14·0	·984	21·5
30	3 58·3	53 5·0	10·6	65·1	77	14·2	·983	21·7
40	3 40·3	53 15·5	10·9	65·4	76	14·3	·982	22·0
50	3 22·8	53 25·8	11·1	65·7	75	14·5	·981	22·3
5 24 0	+3 5·7	53 35·8	11·4	66·0	74	14·7	0·980	22·6
10	2 48·9	53 45·7	11·6	66·3	74	14·8	·980	22·9
20	2 32·5	53 55·4	11·8	66·5	73	15·0	·979	23·2
30	2 16·4	54 4·9	12·1	66·8	72	15·1	·978	23·5
40	2 0·6	54 14·2	12·3	67·1	72	15·3	·977	23·7
50	1 45·1	54 23·4	12·5	67·3	71	15·4	·976	23·9
5 25 0	+1 29·8	54 32·5	12·7	67·6	71	15·5	0·975	24·2
10	1 14·8	54 41·5	12·9	67·8	70	15·7	·975	24·4
20	1 0·0	54 50·3	13·2	68·1	70	15·8	·974	24·6
5 25 30	+0 45·5	54 59·0	13·4	68·3	69	15·9	0·973	24·9

The Effect of Reversing a Small Transit Instrument.

By P. A. Curry.

In connection with the International comparisons of longitude by W/T signals during 1926 October and November, Sir Frank Dyson suggested that the transit circle at Helwân should be reversed during the time observations. The transit circle is by Brunner of Paris, and the telescope has an aperture of 55 mm. and a focal length of 750 mm. It is fitted with a moving-wire micrometer. The instrument had previously been reversed to determine pivot errors by means of the striding level, but no transits had ever been taken in the reversed position, owing to the possibility of the instrumental constants being seriously affected. In addition, there was no way to set the circle in declination in the reversed position. However, it was found possible to set the circle with sufficient accuracy by reading with a small lens the point where the fixed clamp intersected the circle, and thus obviating the necessity for moving the microscope mounting each time.

The telescope was raised off the pivots by means of a jack and, after disconnecting the wires of the moving-wire micrometer and the lamp for illuminating the cross wires, the telescope was lifted bodily by two observers holding the ends of the tube respectively, carried round and replaced in the jack, which was then slowly lowered until the telescope took up its seating in the *Ys*. The reversal was done every week, a complete series of observations being taken before and after reversal. Each series consisted of at least five clock stars averaging about 15° south of the zenith and two south stars which were combined with the two furthest north stars to determine *n*. During each transit the level was read four to six times, and two determinations of collimation were made by means of two fixed collimators.

Date.	Clock Slow on L.S.T.		Difference.
	Direct.	Reversed.	
	s	s	s
Oct. 8	55·76	55·86	+0·10
,, 15	58·00	58·07	+0·07
	m	m	
,, 22	1 00·36	1 00·46	+0·10
,, 29	02·53	02·78	+0·25
Nov. 5	05·04	05·24	+0·20
,, 12	07·46	07·66	+0·20
,, 19	09·69	09·88	+0·19
,, 26	11·78	11·98	+0·20
		Mean	+0s·164

Two to three sets of observations were taken in addition each week and were thus in the direct and reversed positions in alternate weeks. The clock used was Shortt No. 1, made by the Synchronome Company, and its behaviour throughout the two months was excellent. The clock

is kept in an inner double-walled room, the temperature of which varied 6·5° C. during the period, the daily range being about 1° C. No attempt is made to control the temperature.

The observations in the direct and reversed positions taken the same night showed a fairly large systematic difference. The clock errors found in the two positions are tabulated below. The interval between the mean time of the transits before and after reversal was about one hour, and the observations are reduced to the same instant by applying a correction for the rate of the clock over this period.

These differences fall into two distinct groups, and it appears at first sight as though some change occurred between October 22nd and October 29th.

If, however, we assume the differences between the eight observed values of D–R as accidental we have :—

(1) P.E. of a difference D–R = ± 0^{s}·043.
Taking residuals of the observed time from each star observed during the two months from the mean of the corresponding set of five stars we get—
(2) P.E. of a determination of time from one star = ± 0^{s}·026, and thus :
P.E. of a determination of time from a set of five stars = ± 0^{s}·012 ; and
(3) P.E. of the difference between two sets = ± 0^{s}·017.
(1) Depends on eight observations only, and (2) on 172 stars, and both include errors in star places.

If the change in the value of D–R was accidental, we might expect (1) to be smaller, but it is based only on eight observations, and the P.E. found does not mean much. The largest departure from the mean value of D–R is 0^{s}·09, which is five times the P.E. (3). It is thus not at all certain that there was any change in D–R, and the difference found may easily be purely accidental.

It must also be remembered that between the observations of D and R on the same night the telescope is lifted from the jack by hand and revolved and replaced in the jack, and although the corrections for b, c, and n are all redetermined, it is highly probable that the instrument has not time to settle down again after it is disturbed. In particular, the instrument is known to have been jarred on November 12th ; and on October 29th, when the largest value for D–R was found, there was a strong wind blowing, and the observations were not as good as usual.

To obtain a better value of D–R, all the observations in the D and R positions were used, not merely those found on the same night. The values of the clock correction found each night were plotted, after applying corrections for an assumed rate of 0^{s}·30 per day in order to save space in plotting. A smooth curve (fig. 1) was then drawn through the D and R observations respectively. These curves were very nearly parallel, and gave a mean value D–R = 0^{s}·13, the extreme values now being 0^{s}·11 and 0^{s}·16, showing that the previous differences between the D–R values were probably accidental, and that there was no sudden change in the value, as appeared at first sight.

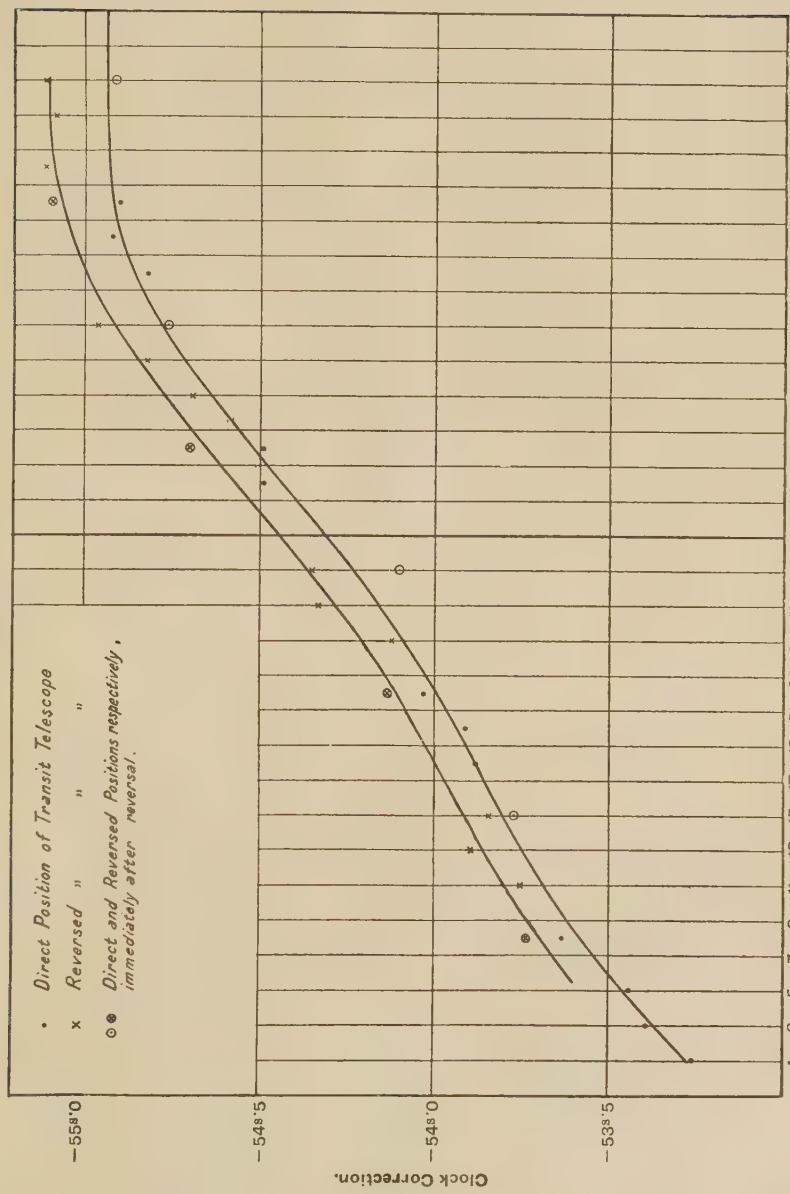

Corrections of Shortt No. 1 from Transit Observations.
• Direct Position of Transit Telescope
× Reversed " " "
⊙ ⊗ Direct and Reversed Positions respectively, immediately after reversal.
Clock Correction.
−55s·0
−54s·5
−54s·0
−53s·5
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
October
November
1926

FIG. 1.

It will be seen that immediately after reversal the observations lie outside the curves, showing that the instrument had not time to settle down properly and that it is sounder to take all the D and R observations.

It has been decided to apply a correction of $-0^s.06$ to all determinations of L.S.T. with the instrument in the direct position.

An attempt has been made to explain this correction. It was first thought that it might be due to the moving-wire micrometer. In the direct position the micrometer is always moved in a direction compressing the spring, and in the reversed position in the opposite direction. To test whether there was backlash in the micrometer screw, two series of readings on the collimator were taken, turning the screw in both directions respectively. The mean of the readings agreed to 0·001 R = $0^s.01$.

As a further test, two circumpolar stars were observed, one at upper and the other at lower transit, the micrometer screw moving in the opposite direction with the star at lower transit. The values of n found from combining these with a south star were $0^s.34$ and $0^s.31$ respectively, showing that the difference D–R is not due to the moving wire.

A pivot correction of $0^s.07$ has been used in the level observations. This was determined by Dr. Knox-Shaw in 1922.

The values of b on the eight nights were :—

	D.	R.	D–R.
	s	s	s
Oct. 8	−0·08	+0·06	−0·14
,, 15	−0·26	+0·19	−0·45
,, 22	−0·23	+0·01	−0·24
,, 29	−0·15	0·00	−0·15
Nov. 5	−0·18	+0·02	−0·20
,, 12	−0·25	+0·01	−0·26
,, 19	−0·10	+0·11	−0·21
,, 26	−0·13	+0·14	−0·27
		Mean	−0·24

This gives a pivot correction of $-0^s.06$, which agrees well with the value used.

The values of n were as follows :—

	D.	R.
	s	s
Oct. 8	−0·45	−0·47
,, 15	−0·51	−0·51
,, 22	−0·37	−0·36
,, 29	−0·45	−0·32
Nov. 5	−0·46	−0·40
,, 12	−0·37	−0·36
,, 19	−0·37	−0·24
,, 26	−0·38	−0·39

As the Azimuth correction should not change on reversal, the values of $-a\cos\phi$ have been computed from the formula $n = b\sin\phi - a\cos\phi$ and are given below :—

	D.	R.	D–R.
	s	s	s
1926 Oct. 8	−0·45	−46	+0·01
,, 15	−0·42	−57	+0·15
,, 22	−0·29	−32	+0·03
,, 29	−0·41	−28	−0·13
Nov. 5	−0·41	−37	−0·04
,, 12	−0·29	−32	+0·03
,, 19	−0·36	−26	−0·10
,, 26	−0·36	−42	+0·06

These differences are not large and are probably only accidental. The collimation readings were as follows :—

	D.	R.	D–R.
	r	r	r
Oct. 8	20·519	0·527	−0·008
,, 15	0·012	0·024	−0·012
,, 22	0·006	0·013	−0·007
,, 29	0·008	0·018	−0·010
Nov. 5	0·009	0·018	−0·009
,, 12	0·489	0·514	(−0·025)
,, 19	0·090	0·497	−0·007
,, 26	0·520	0·498	(+0·022)

On one of the bracketed dates the instrument is known to have been jarred. The other one is also clearly abnormal. The other six days give a systematic difference D–R $= -0^{r}\cdot009 = -0^{s}\cdot08$.

It is not clear how a systematic change in collimation could be caused by reversing the instrument, but it would appear that either such is the case or else there is some error in determining c by the collimator method.

Considering the treatment the instrument is subjected to on reversal, it is surprising that the value of c does not show larger changes.

After applying the correction $0^{s}\cdot06$ to the D and R values, the clock rates between successive transits were calculated (fig. 2). Transits were taken on twenty-six nights during the two months at either two or three nights' interval. To smooth out accidental errors in the transits, the mean of successive rates was taken as the adopted rate. These adopted rates during the two months gave extreme values of $-0^{s}\cdot35$ and $-0^{s}\cdot30$ with a mean of $-0^{s}\cdot33$. If a constant rate of $-0^{s}\cdot33$ a day were assumed for the clock, the probable error of a determination of this from the actual transit observations is $\pm0^{s}\cdot020$. The P.E. of the difference of two transit observations has been shown to be $\pm0^{s}\cdot017$, so that it is scarcely possible to say from transit observations that the rate of the

clock varied from − 0ˢ·33 a day during the whole period of two months. This is a remarkable record for the clock, particularly as no attempt was made to control the temperature.

A report on the determination of the longitude will be published as a Helwân Observatory Bulletin and will include all the observations in detail.

The conclusion, therefore, is that it is not possible to say definitely

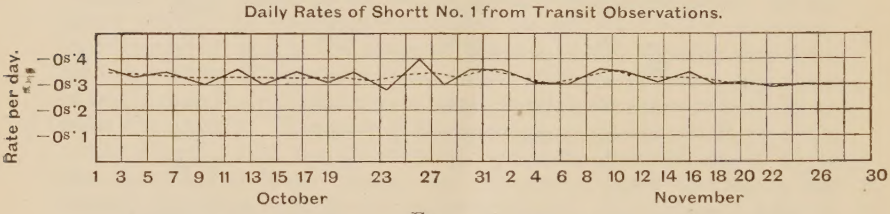

Daily Rates of Shortt No. 1 from Transit Observations.
Rate per day.
−0ˢ·4
−0ˢ·3
−0ˢ·2
−0ˢ·1
1 3 5 7 9 11 13 15 17 19 23 27 31 2 4 6 8 10 12 14 16 18 20 22 26 30
October
November

FIG. 2.

what are the reasons for the change of 0ˢ·13 on reversal, and it is probably a combination of small effects of residual pivot error, personal equation of observer in operating the moving wire in the reverse direction, determination of collimation error, and possibly lateral flexure, although the latter is probably very small with such a small symmetrical instrument. Until further observations are made, it cannot be said that the difference is likely to be constant, but there is every reason to think that it remained sensibly constant during the period under review.

On the Period of YZ Andromedæ. By A. Stanley Williams.

A period of 318·7 days was suggested by the writer for this variable in the *Monthly Notices*, **86**, 82, with a maximum on 1926 July 28, but the observations were not sufficiently numerous for certainty. The star was invisible in a 6½-inch reflector on 1926 Sept. 27, and below 12½ magnitude, but on Oct. 30 it was seen again of about the 10th magnitude, nearly at maximum brightness. The above-mentioned period was therefore evidently not correct. The observations were continued to Dec. 22, when the star had faded to 12½ magnitude.

A satisfactory idea of the visual light-curve could be formed from sixteen observations made during the autumn of 1925 combined with fourteen observations in the autumn of 1926, notwithstanding that there was a paucity of observations during the rise to maximum. The dates of maximum were fixed for 1925 Sept. 10 and 1926 Nov. 5. With the help of the two early photographic observations it is now possible to derive pretty exactly the correct elements of variation, namely,

$$\text{Maximum} = \text{J.D. } 2424402 + 212^{d}\cdot35\ \text{E.}$$

The observed and computed maxima are given below, together with the residuals, which are quite satisfactorily small, considering the circumstances.

E.	Observed Maximum.	Computed Max.	O.−C. d
−39	1902 Dec. 31± = J.D. 2416115±	6120·3	−5·3
−36	1904 Oct. 7± = 2416761±	6757·4	+3·6
0	1925 Sept. 10 = 2424404	4402·0	+2·0
2	1926 Nov. 5 = 2424825	4826·7	−1·7

The next two maxima should occur on 1927 June 7 and 1928 Jan. 5.

Polvarth, St. Mawes,
1927 *April* 2.

Errata.

Page 360. In Table IV., col. 4, the trig. parallaxes are ″·006 larger and the group parallaxes ″·003 larger than the values given in Schlesinger's catalogue. The absolute magnitudes are correspondingly in error.